Terahertz rectangular antenna for biomedical application

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Abstract

In this work we will design a nano rectangular antenna with the new terahertz spectrum for biomedical applications [0.1-4] THz. the proposed antenna has been simulated with different types of medical substrate Arlon AD250C (εr = 2. 5), polymide (εr = 3.5), Rogers RO3003(εr=3) and RO4003C(εr=3.55), the simulation results are very satisfactory in terms of gain, which exceeds 6.556 dBi with a reflection coefficient of -23.703 using Rogers RO3003(εr=3) substrate material .

Keywords

WBAN, terahertz, Antenna ,medical substrate

1. Introduction

Telemedicine is a discipline of medicine that uses information and communication technologies to provide treatment remotely. People can receive healthcare remotely without having to physically visit to a medical center[1].

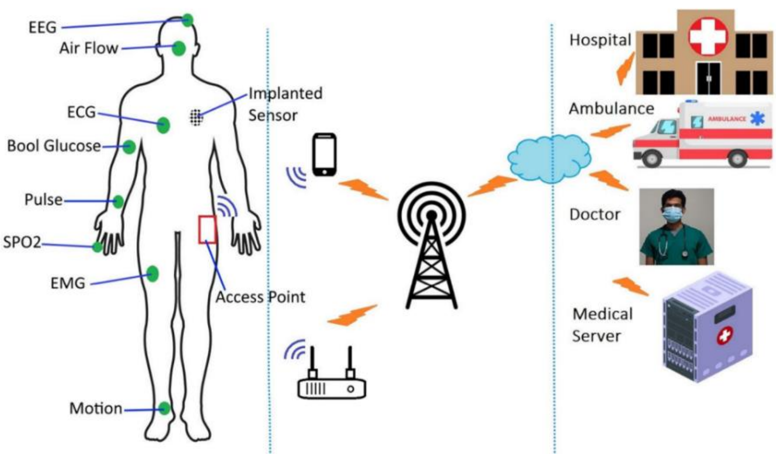

Figure 1: medical WBAN Applications **.**

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Antennas are essential in Wireless Body Area Networks (WBAN) as they enable wireless connections between monitoring equipment and medical instruments and sensors implanted on the patient's body[2]. They can be IN-Body, ON-Body, or OFF-Body[3][4]. In medical technology, antennas require a reliable communications network with constrained bandwidth to transmit real-time data without interfering with other networks[5]. They also require minimal energy consumption to extend battery life and are primarily designed for short-distance communication, with low gain due to their resistance to human interference[6].

To meet this requirement, the terahertz [0.1- 10]THz band, or the so-called far-infrared zone[7], is being used to provide an antenna with a compatible size of the nano-metric order and low energy consumption, with several advantages of note:

1. **High resolution imaging :** Terahertz imaging technology uses electromagnetic waves with wavelengths in the terahertz region to produce pictures of biological tissue. The wavelength of terahertz waves, which is shorter than that of microwaves but longer than that of infrared waves, enables them to penetrate deeper into biological tissue without damaging cells, helping doctors to identify illnesses early and more precisely[8][9].
2. **Possible health risk:** The terahertz band is considered safe for human use due to its non-ionizing nature, unlike X-rays and ionizing radiation. DNA can be damaged by X-rays, potentially increasing the risk of cancer. Terahertz waves, on the other hand, are non-ionizing electromagnetic waves that do not break chemical bonds in molecules like DNA. This makes them ideal for healthcare applications, enabling non-invasive imaging methods that are safe for patients[10].
3. **Use in body scanners:** Terahertz waves can penetrate the skin and detect changes in the density of physically tissue, assisting in the diagnosis of lesions or disorders. Terahertz body scanners offer an advantage over typical medical scanners in that they are non-invasive and do not expose the user to ionizing radiation[11].

In this work we will design a rectangular WBAN nano-antenna in the frequency band [1.48 -1. 55] THz with the different substrate types Arlon AD250C (εr = 2.5),RO4003C(εr=3.55),Rogers RO3003(εr=3) , polymide (εr = 3.5) and gold as a conductive material for on-body application.

2. Antenna designed

A nano rectangular slotted patch antenna was designed using CST software, fed by a microstrip line with a 50 hom impedance. The ground plane and patch are simulated using gold material with an 6 µm thickness, while the dielectric substrate is made of Arlon AD250C (εr = 2.5) with a 5 µm thickness as show in figure 2 . The size of the antenna are calculated using formulas based on the frequency of the application[12]:

$$w = \frac{3*10^8}{2*fr*10^{12}*\left(\frac{eps+1}{2}\right)^{0.5}} \quad (1)$$

$$L = \left(\frac{3*10^8}{2*fr*10^{12}*(epseff)^{0.5}}\right)*10^6 - 2*\Delta l \quad (2)$$

$$Wg = w + 6*h \quad (3)$$

$$Lg = ll + l + 6*h \quad (4)$$

Where: w: the width of the antenna, εr : the dielectric constant of the substrate materiel , l : height of the antenna And h: the height of the antenna.

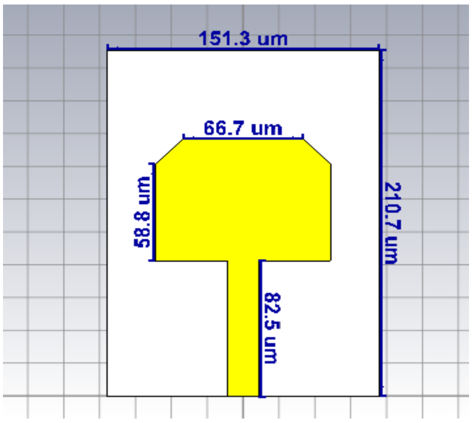


Figure 2: Proposed nano rectangular antenna.

3. Simulation and result of the proposed rectangular antenna

3.1. Simulation and result with Arlon AD250C substrate

Figure 3 shows the simulation result of the return lost with used the Arlon AD250C (εr = 2.5) material of substrate, the reflection coefficient obtained is equal to -34.617 dB with a frequency of 1.48 THz. The Figure 4 and Figure 5 show that the proposed antenna have a VSWR(Voltage Standing Wave Ratio) less than 2 with omni-directional gain of 5.31 dBi .

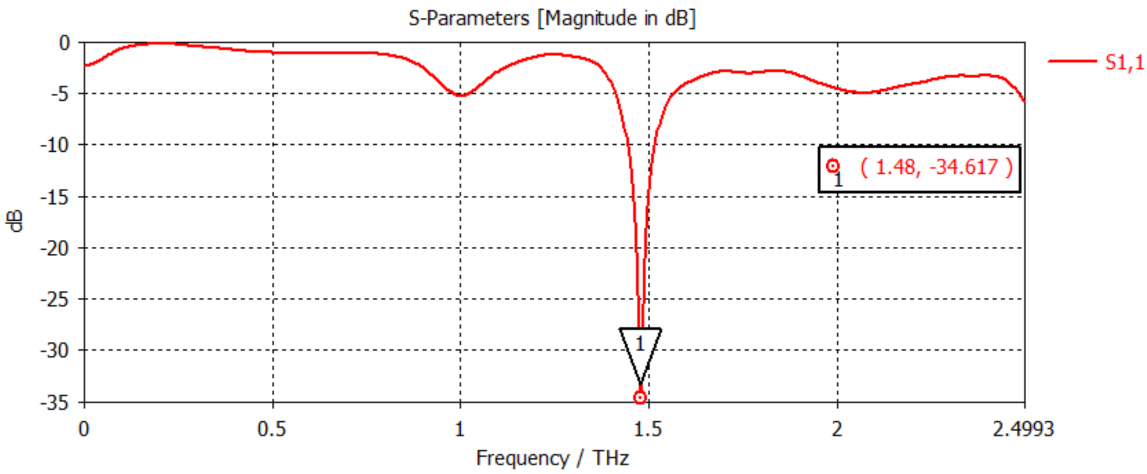


Figure 3: return loss of Proposed nano rectangular antenna with Arlon AD250C substrate.

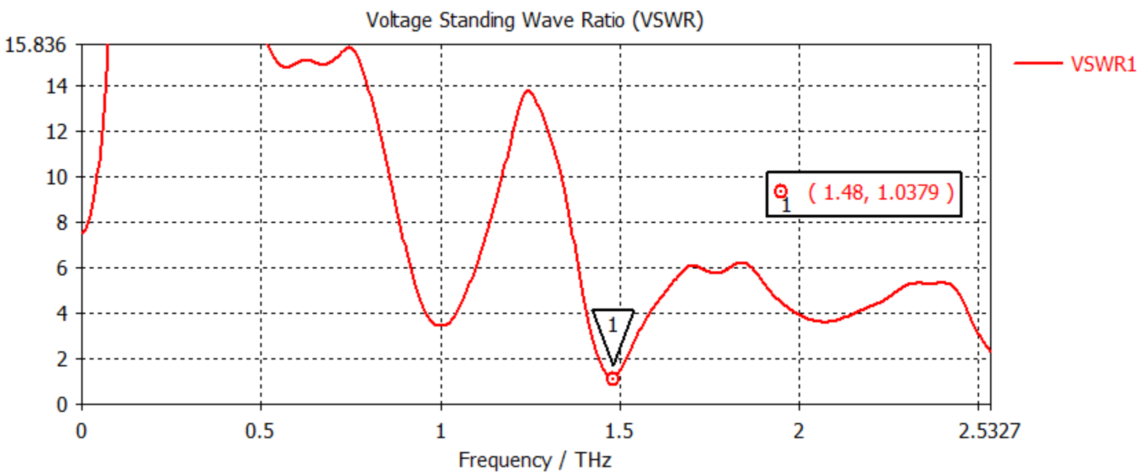
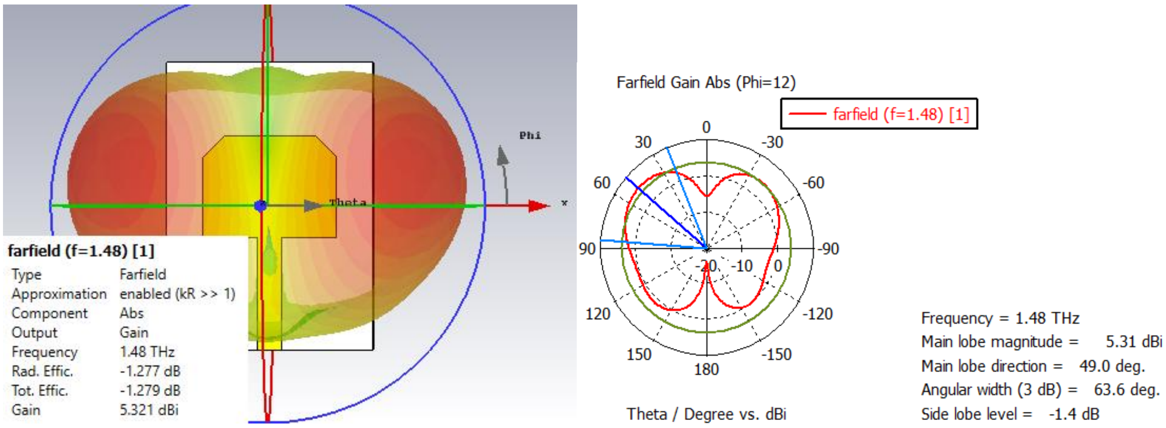


Figure 4: VSWR of Proposed nano rectangular antenna with Arlon AD250C substrate.



(a) (b)

Figure 5: (a)3D Gain ,(b)Polar Gain of Proposed nano rectangular antenna with Arlon AD250C substrate

3.2. Simulation and result with different type of substrate material

The substrate used for a patch antenna significantly impacts its performance. In microwave band, low-constant dielectric substrates are preferred due to their larger effective wavelength, higher radiation efficiency, and wider bandwidth. For the best choice is the optical band WBAN [0.1-4] terahertz we will simulated our proposed rectangular antenna with other substrate materials: RO4003C(εr=3.55) , Rogers RO3003(εr=3) , polymide (εr = 3.5). Simulation results are presented for comparison in figure 6 , figure 7 and figure 8 .

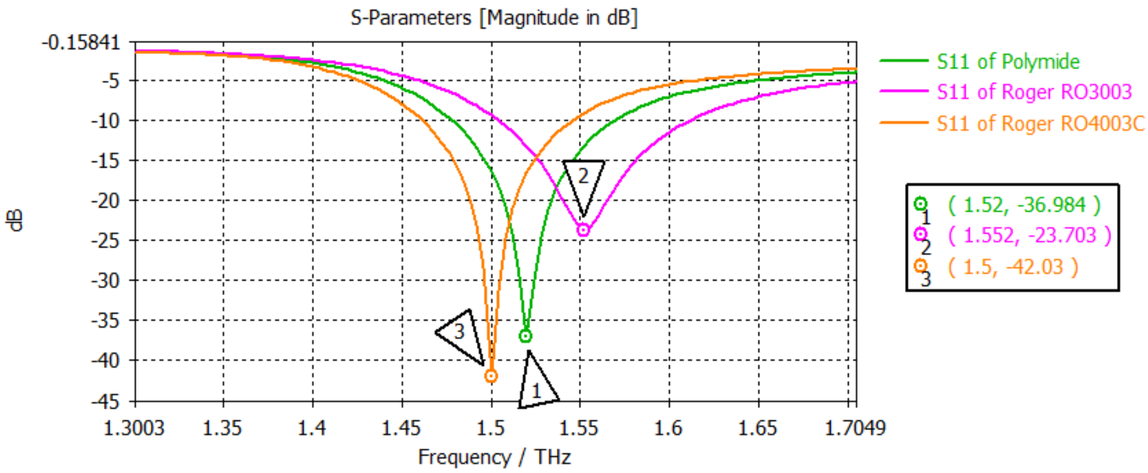


Figure 6: return loss of Proposed nano rectangular antenna with different type of substrate material

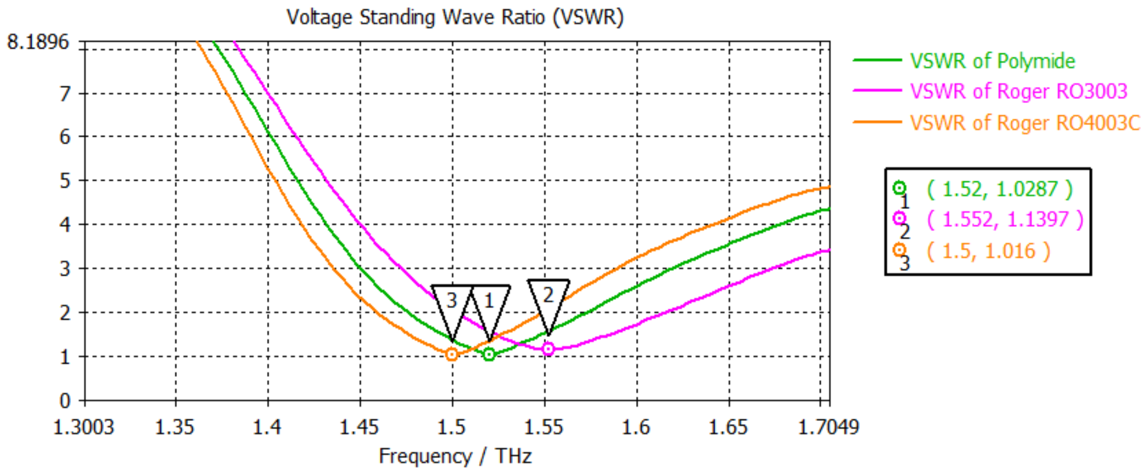


Figure 7: VSWR of Proposed nano rectangular antenna with different type of substrate material.

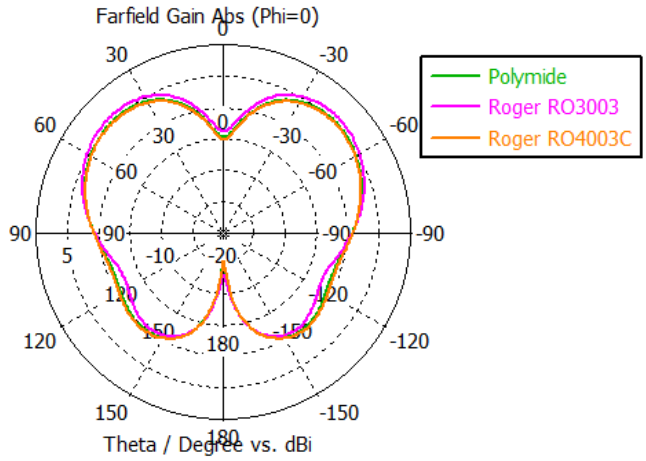
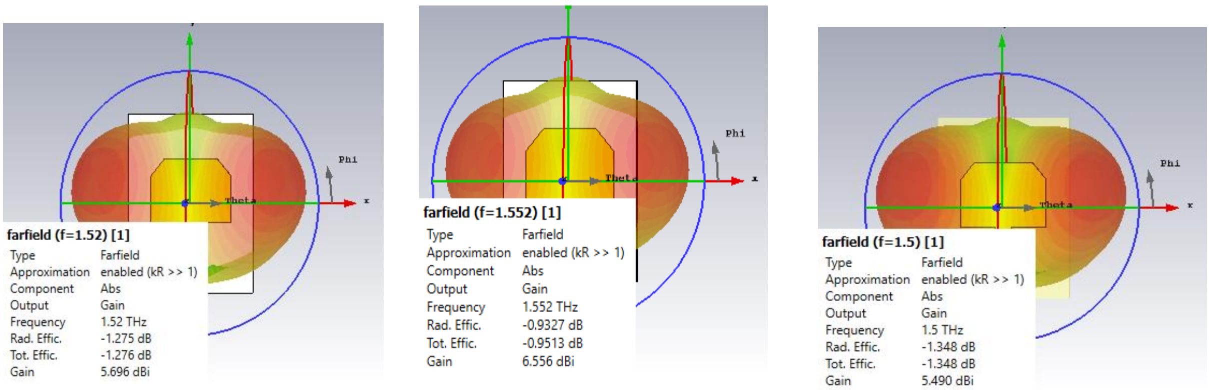


Figure 8: Polar Gain of Proposed nano rectangular antenna with different type of substrate material.



(a) (b) (c)

Figure 9: 3D Gain of Proposed nano rectangular antenna with (a) polymide, (b) Rogers RO3003 (c) and Rogers RO4003C

The simulation result obtained show that several frequencies are obtained by changing the substrate material 1.52 THz, 1,552 THz and 1,5 THz with a return loss of -36.984 , -23.703 and -42.03 and Gain of 5.696dBi, 6.556 dBi and 5.49 dBi with the use of polymide (εr = 3.5), Rogers RO3003(εr=3) and RO4003C(εr=3.55) respectively . The Table 1 summary of all simulation results from our proposed antenna and make a comparison with the different works on WBAN antennas in the terahertz band .

Table 1
Summary of simulation results

	Substrate material	Frequency (THz)	S11(dB)	Gain (dBi)
Proposed rectangular antenna	Arlon AD250C (εr = 2.5)	1.48	-34.617	5.32
	Rogers RO4003C(εr=3.55)	1.5	-42.03	5.49
	Rogers RO3003(εr=3)	1.552	-23.703	6.556
	polymide (εr = 3.5)	1.52	-36.984	5.696
[13]	RT Duriod 6010(εr = 10.2)	0.852	-20	2.5
[14]	FR-4(εr = 4.3)	1.684	-39	5.72
[15]	Quartz (εr = 3.78)	1.02	-28.76	1.44

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4. Conclusion

The optical band, which includes visible light and higher frequencies, is the range of wavelengths in the electromagnetic spectrum. This work presents a nano rectangular patch antenna designed using slit technique for terahertz (THz) electromagnetic waves. The antenna's small size (66.7*58.8µm2) allows for easy integration in various devices and real-time response. The antenna achieves excellent results , with reflection coefficients of -34.67,-36.984 , -23.703 and -42.03, and high gain of 5.32, 5.696dBi, 6.556 dBi and 5.49 dBi at frequencies of 1.48 THz, 1.52 THz, 1,552 THz and 1,5 THz with use different substrate material AD250C (εr = 2.5) , polymide (εr = 3.5), Rogers RO3003(εr=3) and RO4003C(εr=3.55) respectively

. This terahertz antenna offers excellent characteristics and can be used in various applications.

5. References

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